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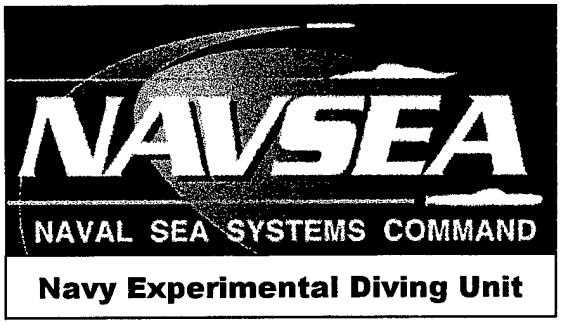

EVALUATION OF ZEAGLE "MK 16 BCD ASSEMBLY" BUOYANCY COMPENSATOR WITH MK 1 Dry Suit Bottle

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19. ABSTRACT: **NEDU was tasked to conduct a survey of commercially available buoyancy compensators (BCs) and perform testing to determine whether the BCs perform satisfactorily. Buoyancy compensator evaluation was conducted in four phases. Phase I included receipt inspection of the buoyancy compensator and technical review of the manufacturer-supplied documentation (instructions / repair manuals). Phase II was Test Pool Evaluation (surface floating attitudes if the BCs were used as life jackets). No failure-mode analysis was conducted. Phase III tested buoyancy / lift capacity in the OSF at 300 fsw (91.9 msw). Phase IV entailed manned dives in the Gulf of Mexico to test diver buoyancy control and operational characteristics.**

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TABLE

INTRODUCTION

Navy Experimental Diving Unit (NEDU) was tasked[1] to survey commercially available buoyancy compensators (BCs) and test them to determine which ones perform satisfactorily in accordance with references (2) and (3). All buoyancy compensators that meet these requirements will be candidates for recommendation to the Authorized for Navy Use (ANU) list. The purpose of this technical report is to document whether the Zeagle "MK 16 BCD Assembly" buoyancy compensator with the alternative inflation source (HP MK 1 Dry Suit bottle) meets those requirements.

METHODS

GENERAL

Each BC was tested and evaluated in four different phases: Phase I, bench test; Phase II, controlled environment (test pool); Phase III, buoyancy lift capacity in the Ocean Simulation Facility (OSF) to 300 fsw (91.9 msw); and Phase IV, open water manned dives to a minimum depth of 60 fsw (18.4 msw). During Phase I, two qualified U.S. Navy divers evaluated each BC for the completeness and adequacy of the supporting maintenance manuals and technical documentation, the skill levels required of divers performing routine repair and maintenance, and the operation of its integrated weight belt and all components. In Phase II, the ability to float an unconscious diver on the surface in a faceup position was evaluated. On the bottom its performance during use by divers in various attitudes (swimming, standing, supine, and prone positions) was evaluated. Phase III consisted of testing and recording buoyancy/lift capability for each BC at 300 fsw. During Phase IV each BC was dove and evaluated in open water by at least ten qualified U.S. Navy divers to a minimum of 60 fsw.

EXPERIMENTAL DESIGN AND ANALYSIS

All BCs were commercial off-the-shelf (COTS) one-size-fits-all items. The task leader or assigned representative was present during the setup and postdive procedures for all BCs.

Phase I testing:

- Two qualified U.S. Navy divers evaluated the ease of operation and maintenance procedures for each model BC.

Phase II testing:

- Testing to 15 fsw (4.6 msw) was in the NEDU test pool. Two concerns were evaluated: whether or not a particular BC was capable of floating an unconscious diver in a face-up position on the surface, and how the BC performed for the diver in various attitudes (swimming, standing, supine, and prone positions) on the bottom. Divers completed a human factor questionnaire after each dive.

Phase III testing

- All BCs were tested to 300 fsw in the OSF. Each was tested for buoyancy/lift capacity three times in two different configurations: a simulated flooded MK 16 with the BC weighted (20 lbs), and a simulated flooded MK 16 without weights. The buoyancy/lift capacity for each configuration was determined by averaging of the three lifts conducted in each configuration.

Phase IV testing

- All BCs were evaluated during a series of open water dives to a minimum depth of 60 fsw. Divers completed a human factors questionnaire after each dive. The manned diving questionnaire statistics were compiled and then averaged. They are presented in Table 1.

EQUIPMENT AND INSTRUMENTATION

No special or proprietary tools were required to perform routine maintenance or repair on the BCs.

a. Phase I:
During bench testing the following equipment was used:

(1) MK 16 MOD 0 UBA and a fully charged MK 1 dry suit bottle (to supply low-pressure air to perform equipment checks)
(2) Manufacturer's instructions and maintenance manuals
(3) Miscellaneous hand tools and adapter fittings
(4) Weights (soft or molded)
(5) BC under evaluation

b. Phase II:
During controlled diving in the test pool the following equipment was used:

(1) MK 16 UBA
(2) Scuba weights
(3) BCs under evaluation

c. Phase III:
During OSF testing the following equipment and personnel were used:

(1) Calibrated spring scale (Model #895, Viking Scale, Shubuta, MS), 0 to 50 pounds (0 to 22.68 kg)
(2) Lanyards, spinnaker shackles, and weight as appropriate to anchor the BCs to the deck in the wet chamber
(3) Simulated flooded MK 16 UBA
(4) Personnel required to man the OSF watch station

(5) Weights
(6) MK 1 dry suit bottle
(7) BC under evaluation

d. Phase IV:
During open water testing the following equipment was used:

(1) MK 16 MOD 0 UBA and related personal diving equipment to conduct MK 16 open water diving operation
(2) Personnel required to man a MK 16 dive station
(3) Open-water diving platform

PROCEDURES

BC evaluation was conducted in four phases: (1) receipt inspection and technical review of manufacturer-supplied documentation, (2) evaluation of diver's floating attitudes on the surface and of various attitudes (swimming, standing, prone, and supine positions) on the bottom, (3) OSF wet chamber evaluation (buoyancy/lift capacity at 300 fsw), and (4) open water dives to test buoyancy control and operating characteristics.

a. Phase I Testing:
(1) Completeness and adequacy of the maintenance manuals and technical documentation
(2) Requirements for special or proprietary tools
(3) Skill levels required to perform routine repair and maintenance
(4) Operation of the integrated weight system
(5) Operation and activation of all BC components
(6) Ease of attaching the BC to a MK 16 MOD 0 UBA

b. Phase II Testing:
Manned dives in the test pool were conducted to evaluate floating attitudes on the surface and various attitudes (swimming, standing, supine, and prone) on the bottom.

c. Phase III Testing:
Buoyancy/lift capacities of the BCs were tested in the OSF wet chamber at a depth of 300 fsw. All divers were required to familiarize themselves with locations of controls on the BC and procedures for attaching the BC to the MK 16 UBA.

A calibrated Viking Spring Scale (Model #895) was attached to the deck grating of the OSF to measure buoyancy. Each BC was attached to the spring scale, and the BC was then fully inflated until the over pressurized dump valve began leaking air. The buoyancy lift was then read from the spring scale and documented. At a minimum, each BC was required to provide 7 lbs of lift in excess of the weight of a flooded MK 16 MOD 0 UBA, per reference (3). The BC was also evaluated for leaks at depth.

d. Phase IV Testing:
Manned open water dives were conducted to a minimum depth of 60 fsw to evaluate buoyancy control and operating characteristics of each BC. Results were recorded in the Manned Diving Evaluation Questionnaire completed by each diver.

RESULTS

PHASE I

The documentation that the manufacturer supplied on the use and technical specifications of the BC, the exploded views/diagrams, and the parts list for the BC was satisfactory. The parts list and technical specifications were included in the buoyancy compensator manual. No special or proprietary tools were needed to conduct routine maintenance or repairs. Skill levels required to perform routine maintenance should be those of at least a basic Explosive Ordanance Disposal (EOD) technician. The integrated weight system made it easy for the diver to add or ditch weights, as required. All BC components were easy to operate and activate.

PHASE III

In the simulated MK 16 UBA flooded configuration without weights the "MK 16 BCD Assembly" averaged 18.7 ± 1.2 lbs more lift than the weight of a flooded MK 16 UBA.

PHASE II/IV

During the manned evaluations (test pool and open water dives) 20 divers evaluated the Zeagle "MK 16 BCD Assembly" in depths ranging from 15 to 60 fsw. Each diver filled out a Manned Diving Evaluation Questionnaire. On a scale of 1—6 (with 4.0 being the minimum mark for an overall acceptable score), this BC scored 4.91.

CONCLUSIONS

During manned diving of the Zeagle "MK 16 BCD Assembly" surface attitude testing, the BC failed to float an unconscious diver in a faceup attitude. However, the ability to float an unconscious diver on the surface in a faceup attitude was not a requirement, per reference (1).

The buoyancy compensator "MK 16 BCD Assembly" has an integrated weight belt system that allows the diver easily to remove and ditch weight from the BC in case of emergency.[4] Each of the weight module pockets are designed to hold a maximum of 20 lbs (40 lbs total) of molded or soft weights. Either one or both sides of the system can be ditched to regain proper buoyancy control. It is suggested that only one side be ditched at a time; this will allow the diver to see whether proper buoyancy has been regained. If not, the other side may be ditched. This system is easy to use and easy to reinstall onto the BC.

RECOMMENDATIONS

Based on the testing reported in reference (3) and reported in Table (1), we recommend that the Zeagle "MK 16 BCD Assembly" (P/N B60040-1) using the MK 1 Dry Suit Bottle (P/N 576197) be recommended for addition on the ANU List. The BC should only be used when incorporated with a Full Face Mask. Since it failed surface floating attitude testing, we do not recommend that this BC be used as a life preserver.

CATEGORY/ CONTROL #	ITEM/STOCK NUMBER	MANUFACTURER	DESIGNATION /MODEL	NOTES AND COMMENTS
CAT I	BUOYANCY COMPENSATOR P/N B60040-1 DRY SUIT BOTTLE P/N 576197	CARLETON LIFE SUPPORT	MK 16 BCD ASSEMBLY WITH MK 1 DRY SUIT BOTTLE	**GENERAL NOTES (1) (2)** AUTHORIZED WHEN INCORPORATED WITH AN APPROVED FULL FACE MASK AUTHORIZED TO 300 FSW WITH H.P. AIR INFLATION SYSTEM PRESSURIZED TO 3000 PSI

Table 1. Human Factors Evaluation of the Zeagle "MK 16 BCD Assembly" Alternative Inflation Source (MK 1 Dry Suit Bottle) Buoyancy Compensator in MK 16 Configuration.

Zeagle "MK 16 BCD Assembly" w/ MK 16 Dry Suit Bottle - MK 16 Configuration									
	#9	#10	#11	#12	#13	#14	#15	#16	#17
QUESTIONNAIRE #	Comfort	Mobility	Donning & Doffing	Neutral Buoyancy Swimming	Neutral Buoyancy Standing	Neutral Buoyancy Supine	Neutral Buoyancy Prone	Intergrated Weights	Attachment
1	5	4	5	3	3	3	3	5	5
2	5	5	5	4	4	4	4	6	6
3	5	4	6	4	4	4	4	5	3
4	6	5	6	6	6	6	6	6	6
5	6	3	6	6	6	6	6	6	5
6	6	5	6	6	6	6	6	6	6
7	5	4	5	5	5	5	5	5	5
8	5	4	6	3	3	3	3	4	6
9	4	4	5	4	4	4	4	5	5
10	5	5	4	5	5	5	5	5	4
11	5	4	5	4	4	4	4	6	5
12	6	5	6	5	5	5	5	6	6
13	4	4	6	5	5	5	5	5	6
14	6	4	6	4	4	4	4	6	5
15	5	4	5	5	5	5	5	5	5
16	6	5	6	6	6	6	6	6	6
17	5	4	6	5	5	5	5	5	5
18	5	5	6	3	3	3	3	4	6
19	5	5	6	5	5	5	5	5	6
20	6	5	6	6	6	6	6	4	6
21	6	6	6	3	3	3	3	6	4
22	6	5	5	3	3	3	3	6	6
23	6	4	5	4	4	4	4	6	6
QUESTION AVERAGE	5.35	4.48	5.57	4.52	4.52	4.52	4.52	5.35	5.35

Note: Questions one through eight pertained to divers information only and were not significant to the overall test results.

Table 1. A series of evaluation dives consisted of ten-man dives per BC. All open water dives were conducted at a minimum depth of 30 fsw (9.4 msw). Divers completed a human factors questionaire after each dive. A set of statistics describing the responses and specific comments were compiled. The BCs were scored on a scale of 1 – 6, with 4.0 being the minimum mark for an overall acceptable score (1 = poor, 4 = adequate, 6 = excellent).

Table 1. Human Factors Evaluation of the Zeagle "MK 16 BCD Assembly" Alternative Inflation Source (MK 1 Dry Suit Bottle) Buoyancy Compensator in MK 16 Configuration.

#18 Over All Rating	#19 Operating Controls	#20 Wearing Gloves	#21 Water Drag	#22 Feel Comfortable	#23 Buckles and Straps	#24 Can EOD Operate	#25 BC Choice	#26 Asset to Fleet	AVERAGE
5	5	Y	Y	Y	Y	Y	Y	Y	4.18
5	5	Y	N	Y	Y	Y	Y	Y	4.82
5	4	Y	Y	Y	Y	Y	Y	Y	4.36
6	6	Y	Y	Y	Y	Y	Y	Y	5.91
6	6	Y	Y	Y	Y	Y	Y	Y	5.77
6	6	Y	N	Y	Y	Y	Y	Y	5.91
5	5	Y	Y	Y	Y	Y	Y	Y	4.91
5	5	Y	Y	Y	Y	Y	Y	Y	4.27
4	5	Y	Y	Y	Y	Y	Y	Y	4.36
5	4	N	N	Y	Y	Y	Y	Y	4.73
5	5	N	N	Y	Y	Y	Y	Y	4.64
6	5	Y	N	Y	Y	Y	Y	Y	5.18
4	5	N	Y	Y	Y	Y	Y	Y	4.91
5	5	N	N	Y	Y	Y	Y	Y	4.82
5	5	N	N	Y	Y	Y	Y	Y	4.91
5	4	N	N	Y	Y	Y	Y	Y	5.64
5	5	N	N	Y	Y	Y	Y	Y	5.00
4	4	N	N	Y	Y	Y	Y	Y	4.18
6	5	N	N	Y	Y	Y	Y	Y	5.27
5	4	N	Y	Y	Y	Y	Y	Y	5.45
5	4	N	N	Y	Y	Y	Y	Y	4.45
5	6	N	Y	Y	Y	Y	Y	Y	4.64
5	3	Y	Y	Y	Y	Y	Y	Y	4.64
								SUB TOTAL	4.91
5.09	4.83								4.92
							Overall Average		4.91

Table 1. A series of evaluation dives consisted of ten-man dives per BC. All open water dives were conducted at a minimum depth of 30 fsw (9.4 msw). Divers completed a human factors questionaire after each dive. A set of statistics describing the responses and specific comments were compiled. The BCs were scored on a scale of 1 – 6, with 4.0 being the minimum mark for an overall acceptable score (1 = poor, 4 = adequate, 6 = excellent).

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